Machinery Messages

The limitations of protecting and managing machinery using vibration "transmitters"

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Some of our customers have explored the use of so-called vibration "transmitters," as part of their critical machinery protection and machinery management programs. In this article, I'll discuss some of the significant limitations of these devices. A related article on page 5, *Vibration "transmitters" cost less than monitors…Fact or fiction?*, examines the economic implications of vibration "transmitters" and whether they really deliver the cost savings that many customers perceive. These articles will help you better evaluate whether "transmitters" really represent an acceptable solution for these critical situations or if a conventional monitoring system is a more suitable choice. For simplicity, I will use the words "monitor" and "protection system" interchangeably.

Why we are qualified to address this topic

Bently Nevada manufactures, sells, services, and installs both protection systems and "transmitters." Therefore, we have enough technical expertise to intelligently comment on the differences between these products. Our vibration "transmitters" include both simple 2-wire devices (our 990 Vibration Transmitter), as well as more advanced 4-wire products (our 1800 Dynamic Transmitor® units). Our experience with these products, and valuable customer feedback, provided the background information for this article.

I knew an article on this topic was needed when one of our largest customers for "transmitters" began to re-evaluate their position. They realized that the justifications that led them to use "transmitters" were not as valid as they originally believed. They are now convinced that machinery protection systems deliver the best value and are actually more cost-effective for their applications. Why was this particular customer so significant? *Because they had been the beta-test site for our 1800 Dynamic Transmitor products and a leading proponent that Bently Nevada develop vibration "transmitters" initially.* When they came back to us and shared their observations, we knew it was time to share this information with the rest of our customers.

What is a "transmitter"?

There are two broad groups of vibration "transmitters":

Basic (2-wire)

- Reduces the complex vibration signal to a single static parameter (peak to peak amplitude, Smax, RMS amplitude, zero to peak amplitude, etc.).
- Makes this single parameter available as a proportional output (usually the ISA-standard 4-20 mA).
- 2-wire device (i.e., loop-powered).

Advanced (4-wire)

- Incorporates some form of self-check (OK circuitry) and may make a NOT OK condition available as a separate output "state" outside the normal range (e.g., NOT OK condition designated by a 2 mA output).
- Provides ground isolation between outputs.
- Preserves the standard "raw" vibration waveform and makes this available via a buffered output. Also preserves the standard conventions and scale factors for the dynamic signal (motion toward the transducer resulting in a positive-going signal) for correct diagnostic plots.
- Allows alternate power sources (not loop-powered) using a 4-wire scheme with connections for:
  1. Power (often +24 Vdc)
  2. Common
  3. Proportional Output (usually 4-20 mA)
  4. Buffered Dynamic Output

The most basic distinguishing feature of a vibration "transmitter" (whether it incorporates basic, advanced, or a combination of features) is that it is a **component**…not a system (Figure 1). It does not incorporate self-contained alarms and is normally a single-channel device; a single transducer input is reduced to a single-parameter proportional output. For a "transmitter" to provide value, it must be part of a larger control system, such as a Programmable Logic Controller (PLC), Distributed Control

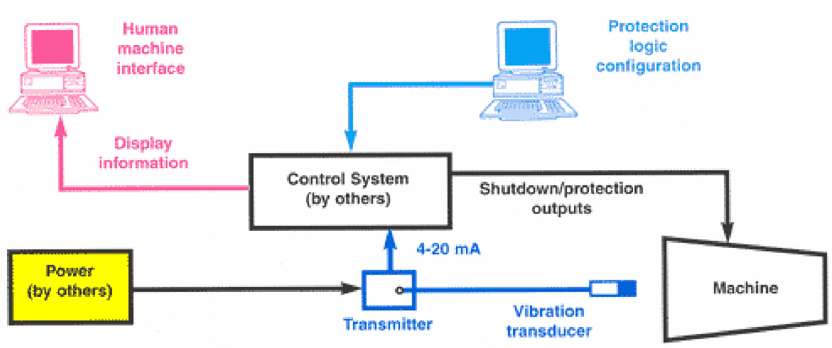

Figure 1
Typical Machinery Protection System layout using "transmitters."

System (DCS), or turbomachinery control system. The control system's function is to accept the "transmitter" signal as an analog input, to compare the proportional signal to pre-set alarm levels within the controller, and to take appropriate control action in the event of alarm conditions.

Why do customers consider "transmitters?"

There are several **perceived** benefits to vibration "transmitters":

- "Transmitters" are less costly than protection systems.
- "Transmitters" are inherently simpler devices and, therefore, more reliable. They have "single point integrity."
- "Transmitters" can use the existing control system as a protection system. Special "stand-alone boxes" (such as a monitor) are not required. This results in a "simpler" vibration monitoring system.
- By using "transmitters" as an input to the control system, training, maintenance, system changes, programming and system simplicity is enhanced. Total life cycle costs are reduced.
- Installation costs are less, since panel space for a monitor is not required .
- The "transmitter" can provide basic machinery information to operators, such as current values, alarm status, and historical trends.
- Machinery diagnostics (i.e., machinery management) can easily be performed by connecting to the buffered outputs on the "transmitter" on an "as-needed" basis.

These are **perceived** benefits and are not necessarily real benefits. The reasons for advocating "transmitters" sound convincing. However, "transmitters" rarely deliver the benefits or value that a cursory glance might suggest. In a typical plant, the following groups commonly use machinery protection and management instrumentation:

1. Rotating Machinery Specialists
2. Operators
3. Instrument and Control Specialists

Let's investigate the implications that vibration "transmitters" have for these three groups.

Rotating Machinery Specialists

The rotating machinery specialist must properly manage machinery. To do this effectively, he must have the proper **information** at his disposal. This is the most fundamental limitation of vibration "transmitters"– they cannot effectively provide machinery management information. When only overall vibration amplitude is available, which is the information supplied by a "transmitter," even the most basic machinery problems such as:

- Unbalance
- Misalignment
- Preloads
- Rubs
- Fluid-Induced Instabilities
- Loose Rotating Parts
- Shaft Cracks

are impossible to diagnose and analyze.

This is because the vibration "transmitter" can convey only a single parameter of the vibration as an output. The additional information needed for properly diagnosing and managing the machinery is discarded (Figure 2).

"But," some may counter, "I can always connect an online system, or even a portable data collector, to the buffered output on my "transmitter," and I will have the full content of the vibration signal available for diagnostics." Let's consider, however, just how **complex and inconvenient** this really is. First, I will discuss using "transmitters" with a permanent, online machinery management system. Then I will describe the difficulties of using "transmitters" with a portable data collector.

Using "transmitters" with online machinery management systems

Figure 3 shows the architecture of a typical "transmitter"-based system used with online machinery management software. Note how complex the architecture is and how many wires must be installed, which increases installation costs.

Since the machinery management system in a "transmitter"-based architecture only receives"raw"vibration signals, it can't use any information generated by the machinery protection system. Alarms, signal OK checks, overall amplitudes, and other parameters must be "re-computed" by the machinery management system. This is inefficient since the machinery protection system must also generate this information. Worse, the alarms, OK checks, and values computed by the machinery management system will never agree exactly with the machinery protection system because of slight variations in the signal processing paths, such as analog to digital conversions, rounding errors, time stamps for events, etc. This leads to the highly undesirable situation of two systems independently computing many of the same parameters. Each system will show slightly (or greatly) different values, statuses, time stamps, event lists, etc. Neither will agree with the other, and confusion will result over which system is correct.

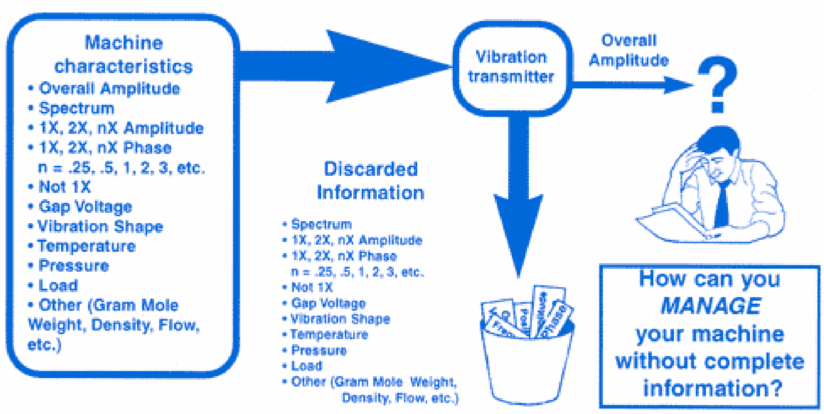

Figure 2
A vibration "transmitter" conveys only limited machinery information.

Attempting to merge the protection and management systems to even a partial extent when using "transmitters" introduces cost and complexity to the protection system. It must now be programmed to output these parameters to a "separate" management system. The protection system must be equipped with additional I/O hardware to transmit alarm statuses and other information to the management system.

While a 4-wire "transmitter" may allow such connections, it is expensive and complicated to connect. If a 2-wire "transmitter" is used, it may be virtually impossible to connect the raw vibration signals to a machinery management system, due to the lack of isolated outputs and the resulting grounding problems that can occur. This can lead to situations in which externally-connected test instruments or machinery management systems can adversely affect the integrity of the protection signals, a wholly unacceptable condition.

Ideally, the machinery protection system will be able to share its information with the machinery management system. Alarms in the protection system will be logged in the management system and will automatically drive waveform and other data capture in the management system. OK checks in the protection system will be recognized by the management system to suppress the collection of "bad data." The result is a highly integrated system that is less costly and technically superior. As Figure 4 shows, this is the basis of Bently Nevada's architecture. The protection system shares this information with the management system via simple pre-engineered interfaces requiring only two cables – not the large amount of wires shown in Figure 3.

Also, many "transmitters" do not preserve the standard conventions for vibration signals, such as scale factors or motion toward the transducer as a positive-going signal. If the data presentation is non-standard, you may reach erroneous conclusions when trying to perform diagnostics. For example, a pair of "transmitters" with these non-standard outputs will produce signals that are one-half the amplitude and are reversed in polarity from standard transducers. This would lead to an orbit that was 50% the usual size, upside down, and reversed (Figure 5). Do you really want to try and mentally "compensate" for these things when doing diagnostics? It is an invitation to make a wrong diagnosis.

Using "transmitters" with portable instruments

While we do not advocate that a portable data collection program alone is an adequate machinery management strategy for most critical machinery, even this method becomes cumbersome with a "transmitter"-based system. First, the "transmitter" must be equipped with a buffered output. This may not be the case on a 2-wire "transmitter." If it is, it may be highly inconvenient to go to the machine skid to open junction boxes and connect to these outputs. If a BNC-style jack isn't provided, you will need to connect a wire directly to a terminal strip. "Transmitters" are also often placed in locations that are not easily accessible.

On many machines, it is desirable to simultaneously collect data from both X and Y probes and a Keyphasor® transducer. This provides important phase information and 2-channel plots, such as Full Spectrum, Orbit, and Shaft Centerline. If the Keyphasor transducer output is on one end of the skid and the other probe(s) are in another location, how convenient or feasible will it be to collect

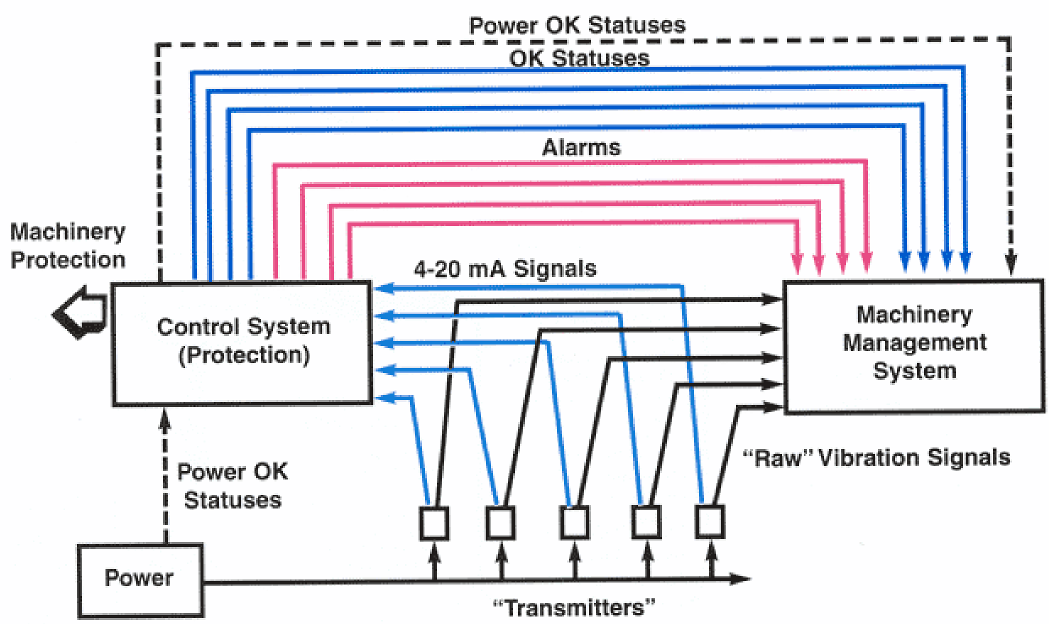

Figure 3
The complexity of Machinery Protection and Machinery Management when using "transmitters."

this data? In many cases, the Keyphasor transducer is not available in a "transmitter-compatible" package. A "conventional" transducer with different supply voltage requirements (-24Vdc), which is not powered by the control system as the "transmitters" are, must be used. This can cause grounding problems, if the test equipment isn't correctly isolated.

There are numerous other issues to also consider. If a "transmitter" has a non-standard buffered output, can the data collector software compensate for this? How do you know the data is OK before you collect it, since the "transmitter" usually doesn't indicate its OK status? How do you avoid grounding problems when you connect to a 2-wire "transmitter?" On some systems, two (or more) "transmitters" will be electrically interconnected if they are connected to a common test instrument or management system. The result will be an erroneous proportional output (the protection signal) that is the average of the "transmitter's" two (or more) readings.

Connection of ground-referenced portable instruments can short out the input to the control system, resulting in a low reading and possible machine trip, depending on the control system configuration. To avoid these problems, some customers have gone to the trouble of actually wiring outputs to a separate "patch panel" or locating a green LED OK annunciator above each connector to convey the signal integrity status before data is collected. The increased cost and complexity make this very unattractive.

I could list other drawbacks, but the message should be clear. It is difficult, expensive, and in many situations virtually impossible, to connect machinery management systems to a "transmitter"-based architecture. When it is attempted, the management system will always be hampered by discrepancies in data between it and the protection system.

"A vibration 'transmitter' is a component...not a system."

As a rotating machinery specialist, you should **insist** on a conventional Bently Nevada protection system coupled with a machinery management system. If not, your ability to properly perform your job is greatly compromised.

Operators

Since vibration "transmitters" can only convey a single proportional value to the control system, the information available to operators to properly perform their job is also greatly compromised. This affects the level of machinery protection that can be provided.

Operator information

Historically, operators have received one, or possibly two, pieces of information from their vibration monitoring systems. Alarm status condition is displayed on an alarm annunciator panel in the control room or on alarm screens on the control system's human machine interface. The second piece of information, overall vibration amplitude, is usually a bargraph-type display on the control system. Occasionally, these current values of overall vibration can also be trended to provide historical information.

At most plants, operators do not review vibration on a continual basis as they do other process conditions. They tend to view vibration data only when an "event" occurs, such as a vibration alarm. Operators then view the information available to them on their control system screens. Since the data is limited, and the operator typically has had only superficial training on its interpretation, he often acts as little more than a "human relay." After the vibration alarm occurs, his immediate response is to call both the machinery specialist (Is this a legitimate machine problem?) and the instrument and control specialist (Or is it an instrument problem?). The operator adds little value except to "relay" to the right people that an alarm has occurred.

A "transmitter"-based system perpetuates this chronic under-usage of the operator. This is because the "transmitter" cannot provide anything more than a single parameter to the control system...overall vibration amplitude. By providing additional information to operators, they can begin to at least partially determine whether their instrumentation is OK or they have a legitimate machine problem. However, this would require multiple "transmitters" for each vibration sensor, which would increase cost and complexity.

Bently Nevada monitoring systems provide far more than just overall vibration amplitude to an operator. In addition to overall vibration amplitude, another machine parameter that could be useful to an operator is the probe gap voltage. This information could warn of instrument-related problems or developing machine problems that are not linked to changes in vibration amplitudes. Bently Nevada pioneered the provision of an additional parameter **intended for operators** we call NOT 1X. This innovative feature shows the operator the level of vibration that is not occurring at the rotative frequency of the rotor. Very simply, many serious machine problems that

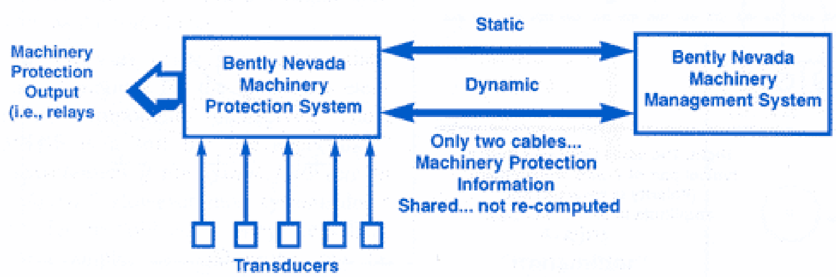

Figure 4
Typical Machinery Management and Protection System layout when using a Bently Nevada Monitoring System.

require immediate attention show up as a relatively large change in NOT 1X, while the corresponding overall vibration amplitude might remain virtually unchanged. Used together, these three parameters (overall, gap and NOT 1X) could significantly help operators accurately communicate the nature and severity of alarms.

"Transmitter"-based systems place tremendous constraints on the quality and cost-effectiveness of machinery management information. Increasingly, Bently Nevada is enhancing its machinery management systems to provide more useful information for operators…not just machinery specialists. An example is Engineer Assist™. The next version of this software will include many enhancements, including being able to post actionable information advisories in real time to operators **right on their control system screen.**

Unfortunately, none of these tools can be cost-effectively incorporated into a system based upon "transmitters." Some systems may totally preclude connections at any cost! Do you really want to restrict your ability to remain competitive in the future by incorporating a "dead end" system, based upon vibration "transmitters?"

Even when more advanced machinery management tools, such as Engineer Assist™, are not incorporated, the monitoring system itself can provide more valuable operator information than "transmitters." This is because Bently Nevada provides monitoring systems with digital communications capabilities. These systems can transmit multiple statuses, error conditions, and parameters for each channel. Hundreds of channels of information from multiple monitoring racks can be easily and conveniently connected to a control system using a single cable. This increases the quality of the information provided to operators, and also reduces the system costs, as less wiring is required compared to the many individual "loops" that must be wired to the control system when using "transmitters."

Enhanced machinery protection

Another consideration for operations is not just the machinery **information**, but also the level of machinery **protection** that a vibration "transmitter" can provide. Since the "transmitter" is limited to a single proportional value for its output, it can only protect the machine based on a single aspect of the vibration signal for each sensor. A monitoring system does not suffer from this constraint and can provide enhanced protection. Bently Nevada monitoring systems allow the user to alarm and even shut down, based on many additional parameters that can be tailored to the specific behavior of the machine and specific problems that are associated with a particular machine design, such as fluid-induced instabilities and shaft cracks.

For example, our 3500 Machinery Management System, can establish the following alarms from a single vibration channel, in addition to the standard overall vibration alarms:

- Acceptable gap voltage regions which indicate shaft radial position inside the bearing. Excessive movement would be indicative of unusual forces acting on the rotor, such as internal or external preloads (e.g., cocked bearings or external misalignment). They could also indicate changes in rotor-to-bearing clearances, such as those caused by a wiped bearing.
- Nonsynchronous vibration (vibration frequencies not occurring at the machine's rotative speed) can be displayed, trended and alarmed. This measurement, termed "NOT 1X" by Bently Nevada, can be a useful indicator of more serious machinery vibration problems that do not occur synchronous with the running speed. Examples include fluid-induced instabilities, rubs, shaft cracks, loose rotating parts, misalignment and compressor surge.
- Synchronous vibration amplitude and phase. This is the vibration component which occurs at shaft rotative speed; it is often referred to as 1X vibration. By establishing proper alarm limits on both the amplitude and phase, you can set acceptable operating regions, which Bently Nevada calls "acceptance regions." This gives operators an easy and graphical assessment of whether the machine is operating normally for

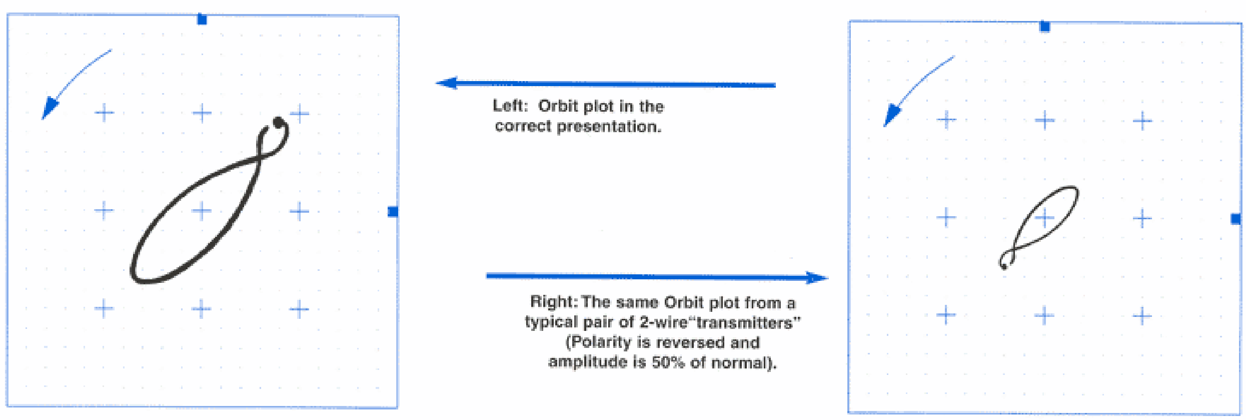

Figure 5
The non-standard output from some "transmitters" can lead to erroneous data presentations.

the particular load, speed, and other process conditions present.

• Acceptance regions can also be built for the vibration component occurring at twice shaft rotative speed (2X).

The monitoring system can provide a more robust and individually-tailored protection system for the machine than can a vibration "transmitter."

Instrument & Control Specialists

Instrument and Control specialists often request "transmitters" because they perceive them to be more convenient and cost-effective. Vibration is usually considered just another 4-20 mA signal. Ironically, some of the most undesirable limitations of vibration "transmitters" are in areas which are important to Instrument and Control personnel.

Reliability

Many people think that a "simple" device, such as a "transmitter," with fewer components, is more reliable than a vibration monitor with its increased components and complexity. While it is true that a vibration transducer system generally has a larger Mean Time Between Failure (MTBF) rate than a monitoring system, this can lead to erroneous conclusions. Some customers have used this argument to lobby in favor of vibration transducers with 4-20 mA outputs rather than a conventional monitoring system.

It is Bently Nevada's experience that the vast majority of system problems that customers report and, more importantly, false and missed trips, can be traced to problems unrelated to the monitor. How can this be if the MTBF numbers for the monitor are not as favorable as those of other system components, such as the transducer?

MTBFs are strictly related to statistical calculations for the life of the electronic components themselves. Thus, MTBF is a sort of "life expectancy" measurement *if the system fails due to "old age."* However, most systems don't die due to "old age"…they are killed. For example, an axial probe may be gapped improperly, leading to a condition where the transducer is saturated and unable to detect excessive thrust movement in a certain direction. This obviously has nothing to due with MTBFs but probably accounts for far more false or missed trips in the field than thrust monitor failures. Likewise, loose cable connectors are often the culprit when customers report monitoring system problems. Again, these problems have nothing to do with component MTBFs and are avoidable if proper installation practices are observed. Radio Frequency Interference and Electromagnetic Interference (RFI/EMI) with field wiring might be another culprit, as can nicked or skinned cable insulation, which can lead to ground loops. The ability to detect and properly deal with these types of system integrity violations lies within the monitor and its OK checks. Thus, **system** reliability is enhanced by using a monitor because of the enhanced self-checks, even though an evaluation, based purely on MTBF considerations, would not lead one to this conclusion.

We strongly caution against evaluations based solely upon MTBF considerations because they do not properly account for actual field experience with system problems. What is the MTBF of a connector? A piece of coaxial cable? A spade lug termination? These are often the areas where problems occur, due to physical abuse or improper installation, long before the electronic components in the monitor fail.

Single Point Integrity

False trips and missed trips reflect poorly on the Instrument and Control group because they are **avoidable** and **costly**, due to process interruptions and asset destruction. "Transmitters" are often recommended because they are perceived as having single point integrity. However, almost all "transmitter"-based applications do not have true single point integrity because they share common power supplies with many points and share common I/O cards with many points in the control system.

Often, users will terminate many 4-20 mA loops into a single I/O card in the control system, such as a 16-input analog card. Thus, while the "transmitters" may be "isolated" one from each other, a single I/O card failure in the control system (e.g., a PLC) could potentially affect many channels…even an entire machine train or trains. This is **not** single point integrity. Also, if the "transmitters" are loop-powered (i.e., 2-wire), the power is coming from the control system. How reliable and stable is this power? Was the control system primarily designed for process control or is it truly suitable for the additional integrity required in a safety shutdown system used to protect expensive assets, such as rotating machinery?

In the case of 4-wire devices, power is

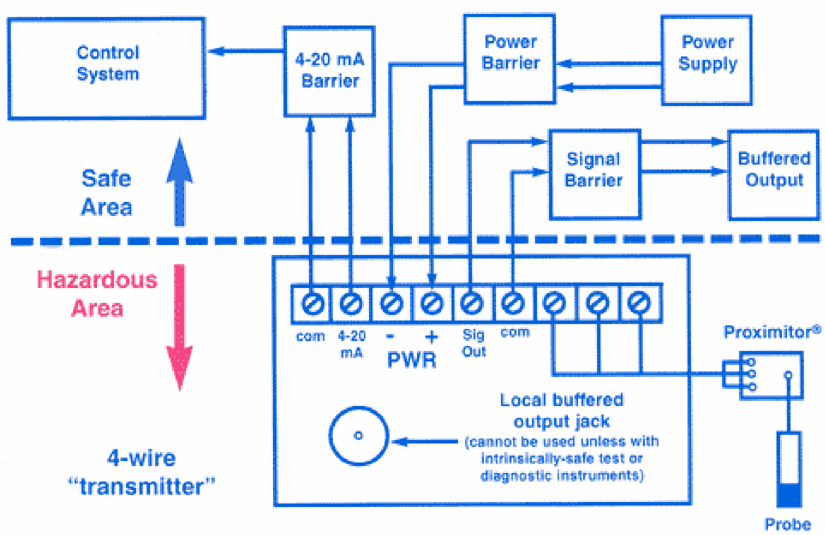

Figure 6
Typical layout for a 4-wire "transmitter" when used in Hazardous Areas.

also a concern. What is the power source? How reliable is it and what checks are performed on the integrity of the power. How are problems conveyed to the control system to suppress "bad data" that would come from the "transmitters" as a result of corrupted power?

Our monitoring systems are specifically built to protect machinery. They do not suffer from these limitations.

Maintenance convenience

Vibration "transmitters" are difficult to maintain and to troubleshoot. Most 2 or 4-wire vibration "transmitters" are "dumb" devices. They can't assess their own "health" or feed back information on the exact nature of their problem. When problems arise, "transmitters" are usually simply swapped out with a spare to see if the problem disappears. Many of the features present in a monitoring system, such as test points, bypass switches, annunciators and displays, error codes, even components as basic as fuses, are often not provided in vibration "transmitters." Consequently, it is almost impossible for an instrument technician to rapidly and confidently assess their integrity and proper operation. When machinery decisions affecting the process are at stake, users can rarely afford to spend hours trying to determine if the instrument is working properly.

When evaluating the true life-cycle cost of a system, ease of maintenance and instrument diagnostics must be considered. "Transmitter"-based systems will rarely be as "user friendly" as a well-designed monitor.

Protection integrity

Since a vibration monitoring system is a self-contained unit that provides all power to, and receives all signals from, its associated transducers, it has much better integrity than a system composed of "components." A system assembled from components, such as stand-alone power supplies, patch panels, vibration "transmitters," I/O cards, controllers, controller power supplies, etc., can't check the proper operation of its individual parts as extensively as an integrated monitoring system can. A monitor can assess its own protection algorithms, microprocessors, power supply integrity, communications networks, relays, and other components in an integrated fashion. Therefore, false and missed trips are minimized.

"A vibration 'transmitter' reduces the complex dynamic waveform to a single parameter."

Customers periodically tell us rather elaborate schemes they have used to perform sensor validation in the control system. For example, they have used PLC ladder logic to examine small fluctuations in the 4-20 mA input signal. Generally, these OK checks are only valid for examining the field wiring between the "transmitter" and the I/O module in the control system. There are many "hidden" faults a typical "transmitter" can exhibit, while still providing an erroneous signal that stays between the 4 mA and 20 mA limits. These OK checks can't provide the full system-wide diagnostics of a monitoring system.

In some cases, these schemes contain hidden dangers. One customer treats any signal over 20 mA as a fault and programs the control system to ignore it. In the event of a sudden machine failure, particularly one involving thrust position measurements, levels can change rapidly and go from a normal reading to an "over range" condition. By ignoring signals over 20 mA, the user will suppress a legitimate machine alarm as a NOT OK condition when the sensor didn't fail at all, but simply slightly increased above full scale. If a control system reading caught the level as it rose, it would cause an alarm, almost immediately followed by a NOT OK condition, producing doubt about the alarm's validity.

Hazardous Area Installations

Many customers in the hydrocarbon industry install our equipment in hazardous area locations. Bently Nevada monitors use a single intrinsic safety barrier per channel to make all signals intrinsically safe. Our 3300 Monitoring System can even be ordered with intrinsically safe barriers already supplied internal to the monitoring rack.

When using "transmitters," the ability to make wiring for the power, proportional output (i.e., 4-20 mA loop), and buffered output circuits intrinsically safe generally requires a separate barrier for each circuit. This results in a minimum of three barriers for a typical 4-wire "transmitter" (Figure 6). The resulting system is both costly and complex. If barriers are used with a 2-wire "transmitter," hazardous area regulations may totally preclude **any** additional connections to a permanently-installed machinery management system.

Hazardous area installations, such as Zone 1 in Europe and Division 1 in North America, place even more restrictions on the use of "transmitters." The requirement for numerous barriers for each "transmitter" greatly increases installation costs.

Conclusion

Vibration "transmitters" have limitations that affect machinery specialists, operators, and instrument and control specialists. The most critical of these limitations, however, is the inability of a "transmitter"-based system to effectively provide the information necessary for machinery management. These limitations encompass both technical and economic issues. Careful consideration of these limitations will most often identify the vibration "transmitter" as an unwise choice for machinery protection and management.

The vibration monitor, in contrast, represents a much better balance of price, performance, features, and benefits. While the costs of the machinery assets themselves can be significant, the implications of process interruptions can be far more important and can easily exceed the cost of a proper monitoring system. Machinery protection and management are not the right places to "cut corners" in an ever-increasingly competitive marketplace. A high-value monitoring system doesn't cost…it pays!